Structural Transformation of Occupation Employment

Georg Duernecker
University of Mannheim

Berthold Herrendorf
Arizona State University

February 9, 2017

Motivation

Structural Transformation

- **As economies develop, labor is reallocated across broad sectors:**
  - goods sectors shrink;
  - service sector grows.
- **This reallocation is called structural transformation (ST).**
- **ST matters for the aggregate outcomes when the sectoral composition matters.**

Which Broad Employment Categories are Most Informative?

- **Literature:** broad categories of (generic) NIPA *industries* (“sectors”).
- **Alternative:** broad categories of Census *occupations*.

Examples for the different categorizations

- **Broad categories of industries**
  - Goods
    - labor from industries that produce tangible value added
    - example: agriculture, forestry, and fishing
  - Services
    - labor from industries that produce intangible value added
    - example: wholesale and retail trade.

- **Broad categories of occupations**
  - Goods
    - labor from occupations that produce, process or transform tangible output.
    - example: skilled agricultural, forestry, and fishery workers
  - Services
    - labor from occupations that produce intangible output
    - example: managers

Reasons for studying ST of occupation employment

- **Occupations crucial for many labor–market outcomes**
  - Human capital and skills (Kambourov-Manovskii)
  - Job polarization (Autor–Dorn)
- **Occupations not affected by relabelling resulting from outsourcing**
  - Janitorial labor
    - employed by manufacturing plant is industry employment;
    - purchased by manufacturing plant is service employment.
  - Whether it's industry or service labor is just relabelling!
  - But a janitor is a service occupation that is invariant to relabelling.

Our contribution

- **Establish stylized facts about ST of occupation employment**
  - Standard patterns of ST hold for occupation employment.
  - The employment share of service occupations rises in all sectors, which is the opposite of what outsourcing implies.
- **Develop a new model of ST of occupation employment**
  - accounts for the stylized facts
  - formalizes what drives the reallocation between industries and between occupations (common driving force and interaction between the two)

Evidence

IPUMS International

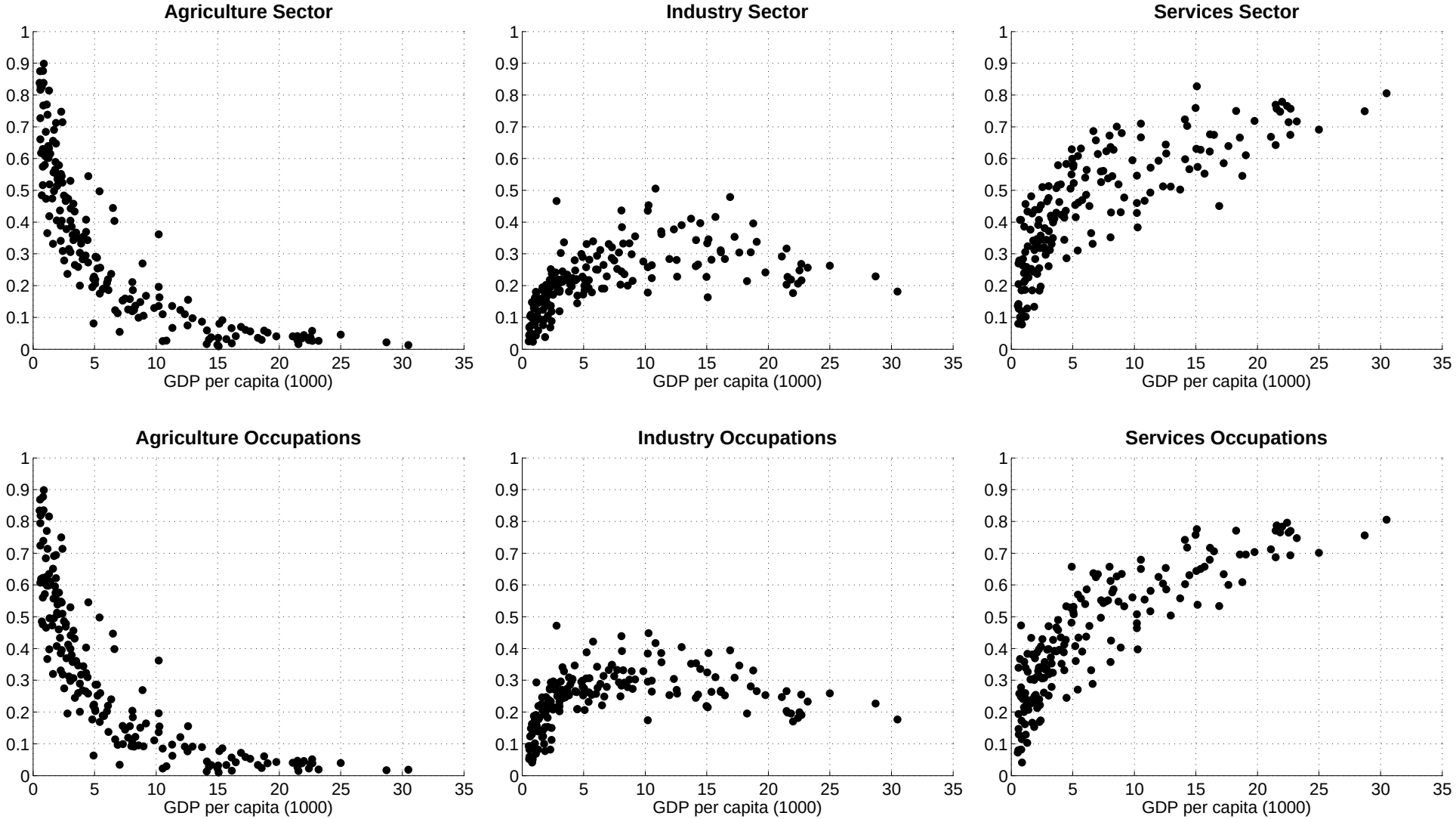
- **182 censuses from 67 countries including 19 African ones**
- **Most economic activity in the world**
  - more than 3/4 of the world population;
  - each of the five most populous countries;
  - more than 2/3 of world output;
  - GDP per capita difference larger than 50.

Aggregation of occupations

Basic principle

- **Goods occupations**
  - Produce, process or transform tangible output.
  - “Blue–collar or brawn–intensive occupations”.
- **Service occupations**
  - Produce intangible output.
  - “White–collar or brain–intensive occupations”.

ST for sectors and occupations



Four stylized facts (aggregating agriculture and industry into goods)

1. **Labor is reallocated from goods to service sector.**
2. **Labor is reallocated from goods to service occupations.**
3. **The goods sector is more intensive in the goods occupation; the service sector is more intensive in the service occupation.**
4. **In each sector, labor is reallocated from goods to service occupations.**

More on stylized facts 3. and 4.

	Goods sector			Service sectors		
GDP per capita (1990 int. $'s)	1,000	15,000	30,000	1,000	15,000	30,000
employment share of ...						
... **goods occupations**	97.3	73.5	42.1	18.7	13.8	9.9
... **service occupations**	2.7	26.5	57.9	81.3	86.2	90.1

[a] Shares are in percent and are from fitted curves.

Model

We want our model to be consistent with SFs 1–4 plus 3 additional SFs from literature

5: The value added share of service sector increases and of goods sector decreases.
6: The price of value added from goods relative to service sector increases.
7: Labor productivity increases more in the goods than the service sector.

Need three key features

- Value added is disaggregated into broad categories of industries (“sectors”).
- Labor is disaggregated into broad categories of occupations (“types”).
- Technological progress augments occupation labor.

Environment

- **Notation**
  - upper–case indexes for sectors;
  - lower–case indexes for occupations.
- **Three sectors**
  - investment Y_{Xt} (numeraire);
  - consumption goods Y_{Gt};
  - consumption services Y_{St}.
- **Two types of labor**
  - goods occupations N_{gt};
  - service occupations N_{st}.

- **Investment technology**

$$Y_{Xt} = A_X K_{Xt}$$

  - where A_X is the (constant) TFP of producing investment goods.
  - AK technology implies that labor is reallocated only between consumption sectors.

- **Consumption technologies**

$$Y_{Jt} = K_{Jt}^{\theta} L_{Jt}^{1-\theta}$$

  - where

$$L_{Jt} = \left[\alpha_J (A_{gt} N_{Jgt})^{\frac{\sigma-1}{\sigma}} + (1-\alpha_J)(A_{st} N_{Jst})^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}}$$

  - $\sigma \in (0, \infty)$ is the elasticity of substitution (with $\sigma = 1$ Cobb–Douglas)
  - standard model results as special case for $\alpha_J = 0, 1$, or $\sigma = \infty$, or $A_{gt} = A_{st}$

- **Lifetime utility**

$$\sum_{t=0}^{\infty} \beta^t \log(C_t)$$

  - where

$$C_t = \left[\alpha_U (C_{Gt})^{\frac{\varepsilon-1}{\varepsilon}} + (1-\alpha_U)(C_{St})^{\frac{\varepsilon-1}{\varepsilon}}\right]^{\frac{\varepsilon}{\varepsilon-1}}$$

  - $\varepsilon \in (0, \infty)$ is the elasticity of substitution (with $\varepsilon = 1$ Cobb–Douglas).

- **Endowments**
  - Positive initial capital stock $K_0 > 0$; capital can be used in both sectors.
  - One unit of labor in each period;
    labor can be used in both sectors and both occupations
    (this assumption would have to change if we wanted to study wage differences).

Analytical Results

Generalized balanced growth path

- Since our model features reallocation of labor between sectors and occupations, ratios won't be constant and imposing BGP would be too strong.
- We focus on Generalized Balanced Growth Path (GBGP)
  - GBGP is an equilibrium with constant real interest rate.
  - Trivially exists here because of the AK technology in the investment sector.

Proposition 1

- *Suppose that* $\gamma \equiv \beta(1 + A_X - \delta) > 1$.
- *Along the unique GBGP, the following variables grow at factor* γ*:*
  aggregate and sectoral capital; consumption expenditure; GDP; investment; wage.

Proposition 2

Recall the functional–form assumptions

$$L_J = \left[\alpha_J (A_g N_{Jg})^{\frac{\sigma-1}{\sigma}} + (1-\alpha_J)(A_s N_{Js})^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}}$$

$$C = \left[\alpha_U (C_G)^{\frac{\varepsilon-1}{\varepsilon}} + (1-\alpha_U)(C_S)^{\frac{\varepsilon-1}{\varepsilon}}\right]^{\frac{\varepsilon}{\varepsilon-1}}$$

Key parameters

- Relative weights: α_S, α_G
- Elasticities: σ, ε (= 1 Cobb–Douglas)
- Labor–augmenting technological progress: A_g, A_s

Proposition 2

- *Suppose that* $\gamma \equiv \beta(1 + A_x - \delta) > 1$.
- *There is a unique GBGP. Along the GBGP, all aggregate variables grow at factor* γ
- *The GBGP is consistent with SF 1–7 if and only if the parameters satisfy:*

  a) $\varepsilon < 1$ (sector value added are complements in utility function)
  b) $\alpha_S < \alpha_G$ *(goods sector uses goods occupations more intensively)*
  c) $\sigma < 1$ *(occupations are complements in production functions)*
  d) $A_g/A_s \uparrow$ *(technological change faster for goods occupations)*

- **Note:**
  - Proposition 2 needs *uneven occupation–specific* technological progress.
  - Proposition 2 does not need *uneven sector–specific* technological progress.

Summary Intuition

- **Two forces generate reallocation of labor to service occupations:**
  - substitution of labor between occupations within each sector
    (results from uneven technological progress at the occupation level);
  - substitution of labor between sectors
    (results from uneven technological progress at both the occupation and sector level).

- **This suggests broader notion of ST than reallocation of sectoral employment.**

Examples for goods–occupation biased technological change

- **Goldin and Katz (2008)**
  - In the 19. century manufacturing technologies replaced skilled artisans.
- **Baumol (1967)**
  - Lack of technological progress in the production of labor intensive services.
- **Autor and Dorn (2013)**
  - Since the 1970s ICT led to routine–biased technological change.
  - Routine–biased technological change replaced mostly goods occupations.

Quantitative Results

Question

- Proposition 2 specifies under what conditions we match SF 1–7 qualitatively.
- How far can our model go quantitatively?

Calibration strategy

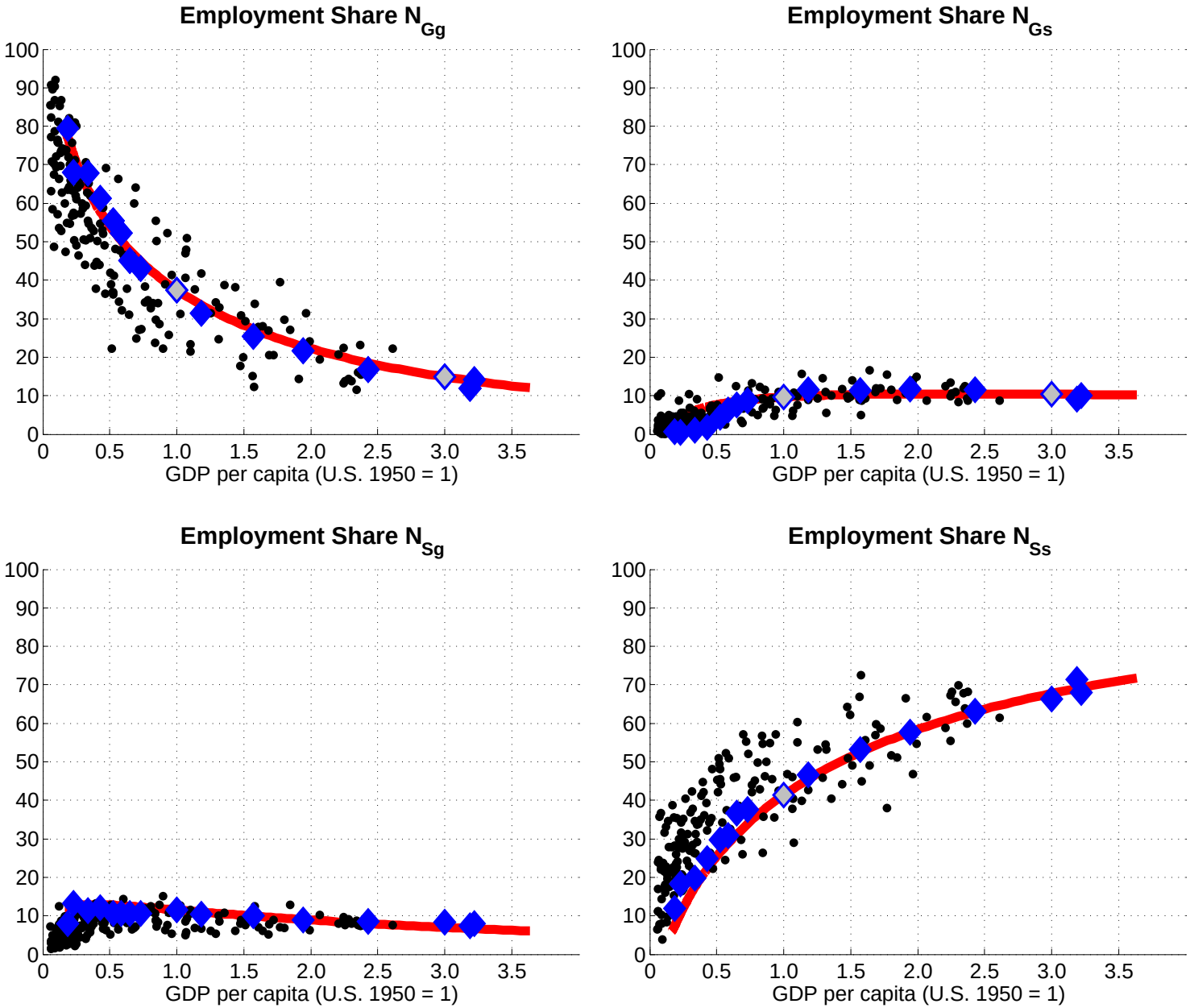
- Standard values when possible
- Joint calibration to targets from U.S. 1950–2000: $\sigma, \alpha_G, \alpha_S, \alpha_u, A_{g,2000}, A_{s,2000}$
- Assume that relative growth rates of technological change apply everywhere

Targets and Model Predictions

	Model		U.S. Data	
Increase in per capita GDP (in 1990 prices) 1950 to 2000	3		**3**	
Capital share in total income	1/3		**1/3**	
Capital–to–output ratio	3.33		~ 3	
Investment–to–output ratio	0.19		0.23	
	1950	**2000**	**1950**	**2000**
Employment share of goods occupations in goods sector	0.38	0.15	**0.38**	**0.15**
services occupations in goods sector	0.10	0.10	**0.10**	**0.10**
goods occupations in services sector	0.12	0.07	**0.12**	0.08
services occupations in services sector	0.41	0.68	**0.41**	0.66
Relative labor productivity of goods to services	1	2.8	1	2.2
price of goods to services	1	0.36	1	0.51
Nominal expenditure share of services	52.8	74.7	39.2	63.9

Reallocation around the world with occupation–specific technological progress only

- Assume the same technological processes as in the US.
- Run them backwards to get GDP right.


Employment Share N_{Gg}
Employment Share N_{Gs}
Employment Share N_{Sg}
Employment Share N_{Ss}
GDP per capita (U.S. 1950 = 1)
0
10
20
30
40
50
60
70
80
90
100
0.5
1.0
1.5
2.0
2.5
3.0
3.5

A Non–targeted Implication of the Model: Occupation Forcecasts

Table 1: Change in employment share of goods occupations (in %)

	72–85	**78–90**	**82–95**	**88–00**	**90–05**	**00–10**	**04–14**
Data	-6.6	-6.2	-5.3	-3.2	-3.4	-3.7	-2.7
BLS forecast	-3.9	-1.8	-1.5	-3.0	-2.9	-1.0	-1.0
D–H forecast	-7.9	-6.6	-6.7	-5.7	-6.7	-3.8	-3.5

Conclusion

- **We have:**
  - established stylized facts about ST of occupation employment
  - developed a new model of ST that
    - has broad categories of industries and occupations;
    - has occupation–specific technological change as the force behind ST;
    - generates the stylized facts.
- **We plan to generalize this model in at least two dimensions:**
  - have more than two sectors/occupations;
  - include entry costs into the occupations.

Appendix: Additional Tables and Figures

Available census observations

Armenia (2011); Argentina (1970,1980); Austria (1971,1981,1991,2001); Bolivia (1976,1992,2001); Brazil (1960,1970,1980,1990,2000,2010); Burkina Faso (1996); Cambodia (1998,2008); Cameroon (2005); Canada (1971,1981,1991,2001); Chile (1960,1970,1982,1992,2002); China (1982,1990); Colombia (1964,1973); Costa Rica (1973,1984,2000,2011); Domenican Republic (1960,1970,1981); Ecuador (1962,1982,1990,2001,2010); Egypt (2006); El Salvador (1992); France (1962,1968,1975,1982,1990,1999, 2006,2011); West Germany (1970,1987); Ghana (1984,2000,2010); Greece (1971,1981,1991,2001); Guinea (1983); Haiti (1982,2003); Hungary (2001); India (1983,1987,1993,1999,2004); Indonesia (1971,1976,1980,1985, 1990,1995); Iran (2006); Ireland (1971,1981,1991,1996,2002,2006,2011); Italy (1997); Jamaica (1982,1991); Kyrgistan (2004); Liberia (2008); Malawi (1987,1998,2008); Malaysia (1970,1980,1991,2000); Mali (1987,1998,2009); Mexico (1970,1990,1995, 2000, 2010); Mongolia (2000); Morocco (1982,1994,2004); Mozambique (1997,2007); Netherlands (2001); Nicaragua (1971,1995,2006); Nigeria (2008,2009,2010); Pakistan (1973); Panama (1960,1970,1980,1990,2000,2010); Paraguay (1962,1972,1982,1992,2002); Peru (1993,2007); Philippines (1990); Portugal (1981,1991,2001,2011); Puerto Rico (1990,2000,2005,2010); Romania (1992,2002); Rwanda (2002); Senegal (1998); Sierra Leone (2004); Slovenia (2002); South Africa (2007); Spain (1981,1991,2001); Sudan (2008); Switzerland (1970,1980,1990,2000); Tanzania (2002); Turkey (1985,1990,2000); Uganda (2002); U.K. (1991,2001); Uruguay (1963,1996,2006); U.S.A. (1960,1970,1980,1990, 2000,2010); Venezuela (1981,1990,2001); Vietnam (1999, 2009); Zambia (1990,2000,2010).

Broad categories of occupations

- **Goods occupations**
  - **Agriculture occupations:** elementary agricultural occupations; skilled agricultural, forestry, and fishery workers.
  - **Industry occupations:** elementary industry occupations; crafts and related trades workers; plant and machine operators and assemblers.
- **Service occupations:** elementary service occupations; armed forces; clerks; legislators, senior officials and managers; professionals; service workers and shop and market sales; technicians and associate professionals.

Reallocation between sectors and occupations

GDP per capita (1990 int. $'s)	1,000	15,000	30,000
Employment share of			
goods sectors	74.3	38.0	19.9
service sector	25.7	62.0	80.1
goods occupations	77.1	36.6	16.3
services occupations	22.9	63.4	83.7

[a] Shares are in percent and are from fitted curves.

SF 1. Labor is reallocated from goods to service sector.

SF 2. Labor is reallocated from goods to service occupations.

Natural Extensions of the Model

1. Increase in female labor force participation in rich countries

- Women have a comparative advantage in service occupations (Rendall, Manuscript, 2010).
- ST implies the reallocation of labor from goods to service occupations.
- Structural transformation leads to the increase in female labor force participation.
- Ngai and Petrongolo (Manuscript, 2015) build a Roy model in which that is the case.

2. Job polarization

- Job polarization is the decrease in the employment share of the middle–wage occupations and the increase in the employment shares of the low–wage and high–wage occupations.
- Service occupations tend to be both low–wage and high–wage occupation whereas goods occupations tend to middle–wage occupations.
- ST increases the employment of service occupations and decreases the employment of goods occupations.
- Job polarization is a consequence of structural transformation.
- Barrany–Siegel (Manuscript, 2014) build a Roy model in which that is the case.

3. Changes in the degree of unionization

- In the US,
  - labor unions tend to be occupation specific
  - the degree of unionization is higher in goods than in service occupations.
- ST accounts for the decline in the rate of unionization in recent decades.
- Note that over the last century there is a hump–shaped in the US both in the degree of unionization and the share of industry occupations in total employment.

Discussion

- Our model captures that ST causes compositional changes of occupation employment.
  In the three examples, these have consequences for economic issues of interest.
- Our model cannot speak to changes in relative wages
  because we assumed that everyone can supply labor from every occupation.
- The next step on our agenda is to break this assumption
  (for example, by postulating an entry cost into each occupation).